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MASTERARBEIT

Titel der Masterarbeit

Spatio-temporal patterns of human-elephant conflicts at the margin of Thuma Forest Reserve – a case study

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Master of Science (MSc)

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Abstract

Human-elephant conflicts occur where humans and elephants compete for resources. Particularly crop raiding by elephants negatively affects the livelihood of farmers which results in a negative attitude towards elephants and protected areas. Therefore human elephant conflicts became a major conservation concern in Africa and Asia. To analyze the spatio-temporal patterns of human elephant conflicts at the margin of Thuma Forest Reserve (TFR), Malawi, interviews with village heads and small-scale farmers were conducted. Differences in the frequency of damages of individual crops largely reflected availability. Crop raiding followed a seasonal pattern corresponding to the maturing of crops like maize, which was most affected by elephants. The peak of crop raiding was reached two months before harvesting time and occurred in March during the wet season. A second much smaller peak of crop raiding activity was reached in October and may correspond to the maturing of maize in villages with irrigation. Elephant incidents occurred up to a distance of 6.5 km from the reserve's boundary, particularly during the wet season. The likelihood of incidents significantly decreased with increasing distance of villages from the margin of TFR. During the dry season no clear pattern was found emphasizing that the occurrence of elephant incidents outside TFR is spatially less predictable. A GLM testing for effects of months, daytime, irrigation and distance to TFR on the size of observed elephant groups only showed a significant effect of season. From January until May the group size increased continuously and then remained stable until December. Furthermore, our data indicate that the electric fence build at the eastern border of TFR successfully protects villages against crop-raiding elephants. Our study implicates that combining compensation for farmers affected by crop-raiding elephants and the protection of additional villages at the TFR border by an electric fence may be the only mid- to long-term approaches to solve the human-elephant conflict.

Keywords human-elephant conflict, African elephant, crop raiding, group size, irrigation, elephant fence, seasonal patterns, spatial patterns, Malawi

Zusammenfassung

Konflikte zwischen Menschen und Elefanten entstehen dort, wo sie um Ressourcen konkurrieren. Vor allem Plünderungen von Feldern durch Elefanten haben negative Auswirkungen auf die Existenzgrundlage von betroffenen Kleinbauern, was zu einer

negativen Einstellung zu Elefanten und Schutzgebieten führt. Aufgrund dessen wurden Konflikte zwischen Mensch und Elefant zu einem bedeutenden Thema im Naturschutz in Afrika und Asien. Um die räumlichen und saisonalen Muster der Konfliktsituation Mensch-Elefant im Waldschutzgebiet Thuma (Thuma Forest Reserve (TFR)) zu untersuchen wurden Interviews mit Dorfchefs und Kleinbauern durchgeführt. Unterschiede in der Häufigkeit von Schäden an einzelnen Feldfrüchten, zeigen weitestgehend deren Verfügbarkeit an. Die Plünderung von Feldern folgt signifikat einem saisonalen Verlauf in Abhängigkeit vom Reifegrad der Feldfrüchte, wie Mais, der am meisten betroffen war. Der Höhepunkt der Plünderungen wurde im März zur Regenzeit, zwei Monate vor der Erntezeit erreicht. Ein zweiter, aber weitaus kleinerer Höhepunkt wurde im Oktober erreicht und hängt eventuell mit dem Heranreifen von Mais zusammen, in Dörfern in denen Bewässerung betrieben wird. Vorfälle mit Elefanten ereigneten sich bis zu einer Distanz von 6,5 km von der Grenze des TFRs, vor allem in der Regenzeit. Die Wahrscheinlichkeit sich ereignender Vorfälle nahm signifikant ab mit fortschreitender Distanz von Dörfern zu TFR. Während der Trockenzeit wurde kein klares Muster gefunden, was darauf hinweist, dass das Vorkommen von Vorfällen mit Elefanten außerhalb von TFR räumlich weniger vorhersagbar ist. Ein GLM-Test für Effekte von Monat, Tageszeit, Bewässerung und Distanz zu TRF auf die Größe beobachteter Elefantengruppen, zeigte einen signifikanten Effekt nur durch die Saison. Von Jänner bis Mai stieg die Gruppengröße kontinuierlich an und blieb schließlich stabil bis Dezember. Des Weiteren zeigen unsere Daten, dass der Elektrozaun, der im Osten des Reservats errichtet wurde erfolgreich Dörfer gegen plündernde Elefanten schützt. Unsere Studie zeigt, dass die Kombination von Kompensation für betroffene Kleinbauern und der Schutz von weiteren Dörfern an der Grenze zu TFR durch einen Elektrozaun, möglicherweise der einzige mittel- bis langfristige Ansatz ist, um den Konflikt zwischen Menschen und Elefanten zu lösen.

Introduction

The competition for resources increasingly evokes conflicts wherever humans and elephants coexist (Smith & Kasiki, 1999). Particularly the ongoing pressure on natural habitats is increasing the risk of conflicts between elephants and humans. Currently eighty percent of the African elephant's range lies outside of conservation areas (Hoare, 1999). Especially in isolated protected natural elephant habitats surrounded by agricultural land severe human-elephant conflicts occur frequently (Sitati et al., 2005; Naughton et al. 1999). Incidents with elephants predominantly include crop damage through consuming and destroying food and cash crops, sometimes damage of food stores, and injuring and killing people (Smith & Kasiki, 1999).

Human-elephant conflicts are very complex due to the strong connection between socio-economic and ecological factors. In Malawi like in many other African countries most people depend on small-scale farming and, therefore, crop raiding by African elephants (*Loxodonta africana*) can seriously affect their livelihood (Osborn & Parker, 2002). This often results in a strong negative attitude towards elephants and protected areas. Increased poaching and the decline in elephant populations are often consequences (Hoare, 1999).

The acceptance of affected communities towards elephants is essential for the success in conservation. Therefore crop raiding caused by elephants became a major conservation concern (Parker & Osborn, 2001). Consequently, emphasis has to be laid on a better understanding of crop raiding behavior and the identification of spatio-temporal patterns of human-elephant conflicts to optimize management strategies which have to be adapted to particular and potential conflict zones.

The aim of this study conducted at the margin of Thuma Forest Reserve (TFR), Malawi was to analyze seasonal and spatial patterns of the human-elephant conflict to provide basic information for authorities to develop adequate management strategies in favor of elephants, wildlife and humans to enable or to ease a sustainable coexistence. Particularly, we tried (1) to identify crops preferred by elephants, (2) to identify months with the highest crop raiding activity, (3) to predict the likelihood of crop raiding events in relation to the distance to the TFR and (4) to evaluate the success of an recently built electric fence to protect villages from elephants.

Preferred and therefore most affected crops are expected to be basically food crops (such as maize) probably due to their higher nutritional value compared to most cash crops (Hoare, 1999). In particular maize and banana are expected to be targeted by elephants according to a study about temporal patterns of crop raiding by elephants in Uganda (Chiyo et al., 2005).

Seasonal patterns of human-elephant conflicts can reflect the phenology of crop maturity (Hoare, 1999), and they can be expected to appear as a dual season phenomenon (Parker & Osborn, 2001), like in Muzarabani district in the eastern Zambezi valley, Zimbabwe. In consequence, seasonally changing crop availability and the distance from reserves harboring elephant populations may determine the risk of incidents with elephants (Parker & Osborn, 2001). We assume that also around TFR levels of crop raiding activity correspond to harvesting times or specific growth stages of crops and that the number of incidents with elephants is highest at the margin of TFR.

To reduce or even avoid crop raiding events by elephants the erection of an electric fence at the border of TFR was chosen as management measure by the park authorities. In general electric fences are considered as an effective tool against crop raiding elephants although the effectiveness depends on factors such as the design, voltage and maintenance of the fence (Hoare, 2003). A study about the performance of electric fences as elephant barriers in Amboseli, Kenya showed that electric fencing reduced crop raiding to a major extent (Kioko, 2008). In a study from Namibia an electric fence proved to be the only effective method out of different elephant deterrent experiments aiming to reduce crop raiding caused by elephants (O'Connell-Rodwell, 2000). Therefore, we expect that the recently built electric fence also acts as an effective tool for reducing human-elephant conflicts at TFR.

Study area

The study area is situated in vicinity of the TFR in Salima, Dowa, Lilongwe and Dedza District in the central region of Malawi on the escarpment of the Great Rift Valley. The climate is dominated by an annual wet and dry season. Rainy season lasts from November to April and reaches its peak in January and February (Jury & Mwafulirwa, 2002). In the central region of Malawi the mean annual temperature is 24℃, the mean annual rainfall is 801-1000 mm (Mini stry of Natural Resources, Energy and Environment, 2006). TFR covers an area of about 197 km^2 and is characterized by a hilly and partly steep topography. The northern and the southern boundary are formed by the rivers Lilongwe and Linthipe, respectively (Fig. 1). The vegetation is dominated by miombo (*Brachystegia*) woodland and patches of bamboo (Wildlife Action Group 2009).

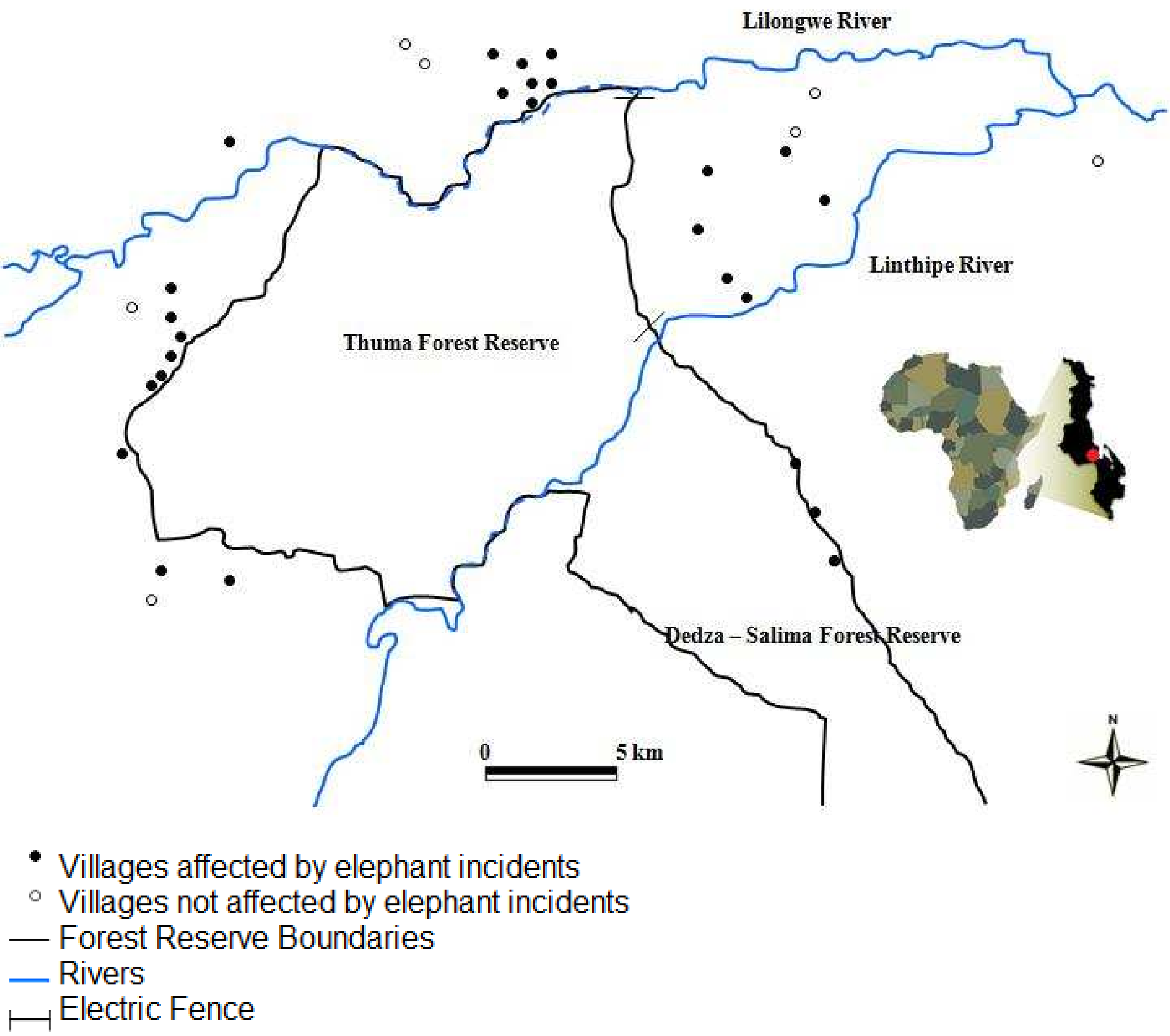

Fig. 1. Maps indicating the location of Thuma Forest Reserve (TFR) in Central Malawi (small map) and the study area (large map). The study area map also indicates villages where village heads and farmers were interviewed to quantify occurrence and abundance of elephant incidents. In the southeast TFR is connected to the Dedza-Salima Forest Reserve. The Linthipe River represents the borderline between both forest reserves.

TFR is under severe poaching pressure (Schenk, 2008). Human settlements are very close to the reserve's boundaries. The protected area is embedded in an agriculturally dominated landscape. Main crops include maize, groundnuts, tobacco and cotton. In some villages (especially in those along the main rivers) irrigation is conducted. The socio-economic situation hardly allows generating alternative sources of income in poor areas in Malawi. People directly depend on their harvest for survival. This fact forces the villagers to protect their fields against elephants and in some cases this results in deadly incidents with elephants. In and around TFR every year humans are killed due to elephant attacks. In the majority of cases attacks were provoked, because farmers attempted to chaise crop raiding elephants from their fields. Because of the already mentioned proximity of some of the assessed villages and fields to TFR, crop raiding events occur very frequently. Therefore a 12 km long electric fence has been erected in November 2009 to protect communities at the eastern boundary of the reserve against crop raiding elephants (Fig. 1).

Standardized surveys have not yet been conducted to estimate the population size of elephants. Rough estimates of the elephant population size in TFR and the attached Dedza-Salima Forest Reserve range between 60 and 200 individuals (Albert Schenk, personal communication).

Occurrence of elephants incidents were recorded for a total of 32 villages located either at the margin of TFR or in distances of up to 15 km from the forest reserve's boundary (Fig. 1; for details of study villages see Table 1). All study villages were situated at an altitude between ca. 570-1000 m asl. Villages were selected according to their location to TFR. At least all bigger settlements in close vicinity of TFR were visited. Study villages in larger distances (7-15 km) to the reserve's boundary were selected randomly also depending on their accessibility. Coordinates of the village centers provided in Table 1 were measured by GPS (Garmin GPSMAP 60CSx). The village center was defined as being located close to the main road, where the highest density of huts and/or the house of the village chief were located.

Table 1. List of study villages (ranked according to the date of access) providing the geographical position (UTM coordinate system) of the village center, the number of inhabitants, the distance to Thuma Forest Reserve (TFR) and the number of interviewees including village heads. * indicates villages protected against elephants by an electric fence since November 2009. [#] indicates villages with irrigation.

Village name	UTM Coordinates (N/E)	Inhabitants	Distance to TFR [km]	Number Interviewees
Chimuthu*	0640891 / 8473930	335	2.00	51
Mphisi 1*	0641179 / 8469143	176	3.00	13
Mphisi 2*	0641095 / 8469056	75	2.75	20
Muvululu*	0640725 / 8471836	340	2.00	30
Mnenula*	0644743 / 8472344	72	6.50	17
Mamadi*[#]	0653957 / 8473775	500	15.00	1
Nkhangayawala*[#]	0643906 / 8474650	36	5.00	4
Kathako Katuwa*	0643978 / 8475753	?	5.00	1
Chisonga*[#]	0643606 / 8474550	89	5.00	4
Malezi	0634864 / 8477996	27	2.00	3
Njala[#]	0635235 / 8477635	73	1.00	5
Machado[#]	0635554 / 8476919	150	0.50	10
Mphonde	0635940 / 8476449	18	0.20	7
Katengeza 1	0631185 / 8477666	24	3.50	1
Mbewa	0630660 / 8477542	33	4.00	1
Kasese 1	0633797 / 8477065	16	2.00	6
Kaojulwende	0625 / 8474[a]	14	3.50	5
Mbawa	0633946 / 8470110	56	1.00	16
Ngolome	0634569 / 8475964	54	0	4
Mdakira	0622943 / 8469298	40	2.00	1
Mwanja	0623136 / 8469842	40	1.50	7
Katengeza 2	0623221 / 8468810	20	0.50	4
Chambakata[#]	0623087 / 8468240	32	1.50	3
Chinyama	0623746 / 8467295	20	0	7
Mapiko 1	0623479 / 8467035	27	0	3
Mgwende Kunsanga	0623073 / 8466625	60	0	5
Kasese 2[#]	0623008 / 8460691	45	1.50	4
Mulamba	0625113 / 8460138	400	1.50	7

Dette	0622550 / 8460060	35	2.00	1
Chinkhowe	0621748 / 8464804	400	0	3
Masitala	0643962 / 8460176	54	0	11
Mzika Manda[#]	0642687 / 8463004	320	0	8

[a] **Coordinates extracted from map.**

Methods

Data collection

Data on elephant incidents were recorded through interviews with small-scale farmers. Therefore, two questionnaires were designed similar to the data collection and analysis protocol for human-elephant conflict situations in Africa for IUCN (Hoare, 1999). Through the questionnaires for the village heads (see Appendix A) information about the villages was collected like the number of village inhabitants or whether irrigation does or does not exist. Furthermore, information about major crops and harvesting times was collected. The importance of crops of a particular village was ranked according to the size of the area covered by a particular crop, and was grouped in following categories: 0 - absent, 1 - less important, 2 - important, 3 - very important. For the main crops the month(s) of harvest was asked. Furthermore, information on occurrences of elephants before and after the erection of the electric fence in the east of the reserve was collected.

After interviewing the village chief, I was referred to individual villagers involved in elephant incidents, in case such conflicts occurred in the respective village during the last years. Such interviews often were done in group meetings. For these interviews an elephant incident form was designed (see Appendix B). The types of elephant incidents were classified as observation only, crop damage and attack of humans. For every incident detailed data were recorded on date, daytime, type of damage (crop raiding, accidental damage e.g. by trespassing only), damaged crops and other damages (e.g. food storages), and group size, age and sex of the involved elephants. In case of direct conflict situations confrontations between humans and elephants were classified as human injury, human death and others (e.g. chaising) (see Appendix B). All interviews were conducted between 13 February and 15 May 2010.

Statistical analysis

For data analyses only recorded elephant incidents, which occurred between December 2008 and the end of our interviews in March 2010, were considered. Then two temporal replicates are available at least for the main wet season (December 2008-March 2009; December 2009-March 2010). Older incidents were excluded, because details mentioned by the interviewees may have been incorrect due to fading memories.

A linear regression analysis was used to test for a relationship between crop availability and reported crop damages. Crop availability was quantified as the number of villages where the respective crop was mentioned by the village head as one of the main cultivated crops. Information provided by the village heads was also used to quantify the main harvesting times for individual crops. Harvesting phenology for individual crops was quantified by comparing the frequency of harvesting (= number of villages where the respective crop was harvested) between months. Relationships between harvesting frequency of major crops and the total number of recorded elephant incidents in the respective months were analyzed by calculating Spearman rank correlations. Because elephants may favor younger plants of crops over ripe ones at harvesting we calculated Spearman rank correlations not only for the relationship between crop availability at harvesting time at elephant incidents but also for crop availability one and two months before harvesting.

To test for differences in the number of elephant incidents and crop availability between dry and wet season in villages with and without irrigation Pearson Chi-square tests were calculated. Logistic regression analysis was used to test if the likelihood of elephant incidents decreases with increasing distance of villages to the boundary of TFR. Regressions were calculated including all reported elephant incidents and only including record from the wet and dry season, respectively.

Wald statistics were used to evaluate the univariate effects of season (wet and dry season), distance of villages to the border of TFR and the interaction between both predictor variables on the occurrence of elephant incidents in a Generalized Linear Model (GLM; with log-link function). A GLM was also used to test for effects of daytime (diurnal or nocturnal activity), months, distance to TFR margin and irrigation (yes, no) on the size of elephant groups recorded outside TFR by villagers.

Furthermore, we evaluate if the elephant fence built at the eastern border of TFR successfully protected villages against crop-raiding elephants. Therefore, a Pearson Chi-square Test was calculated testing if elephant incidents occurred less frequently in villages behind the fence than in unprotected villages after the fence was built. Because for the time periods before and after the fence was built only wet season data were available within the time frame between December 2008 and March 2010, dry season data were excluded from this analysis.

Adequate data transformations were applied to achieve a normal distribution of data whenever possible. All statistical analyses were calculated with Statistica version 7.1 (Statsoft, Inc. 2005).

Results

In total 212 elephant incidents were recorded, not including 45 incidents for which no detailed information available, because the reports were received through a third person. Therefore, these elephant incidents were not included in any analysis. The mean number of recorded incidents (± SD) per village was 6.53 (± 10.19) or 8.04 (± 10.78) when excluding six villages from which no elephant occurrences were recorded. A maximum number of 50 incidents was recorded for the village Chimutu.

Crop damages and crop availability

The crop which is by far the most affected by raiding elephants was maize (183 recorded damages), followed by banana (96), peanut (94), sugar cane (51), pumpkin (33), mango (30), tomato (20), and sweet potato (19). Other cultivated crops and fruit trees are only affected to a minor extent (each <12 recorded damages) (Fig. 2). Especially damage to food crops is severe. Cash crops in our study area, such as cotton and tobacco, are mainly damaged accidentally due to passing elephants.

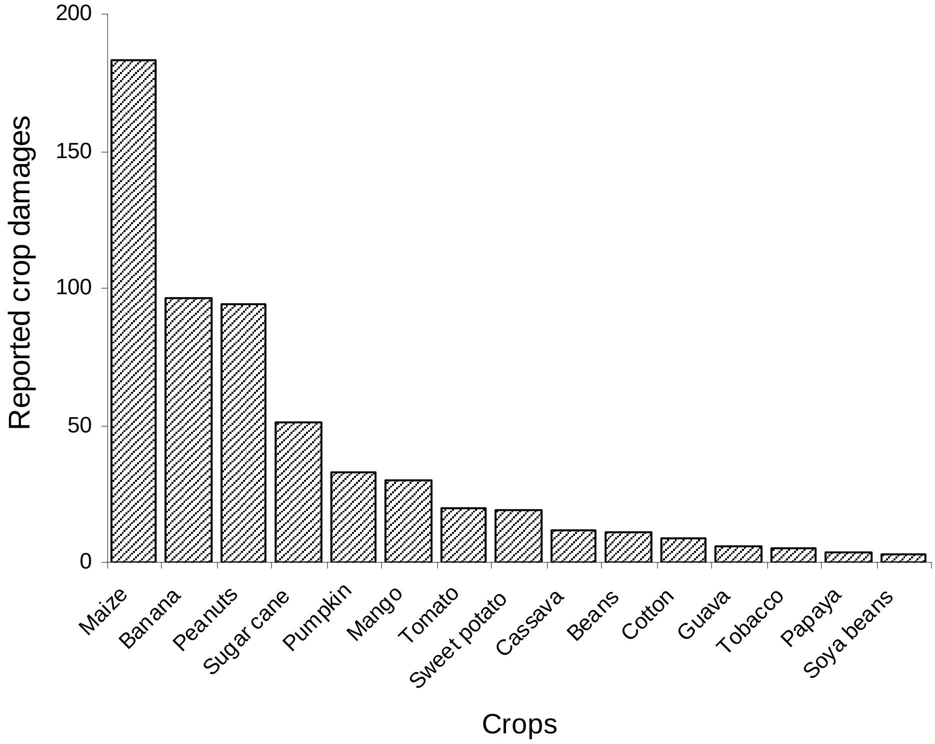

Fig. 2. Number of damages recorded for crops cultivated in the study area.

Reported crop damages increased significantly with increasing crop availability quantified by the number of villages where the respective crops were cultivated according to the village heads (Fig. 3). Maize, for example, was cultivated most frequently in our study area, and was the crop worst affected by crop-raiding elephants.

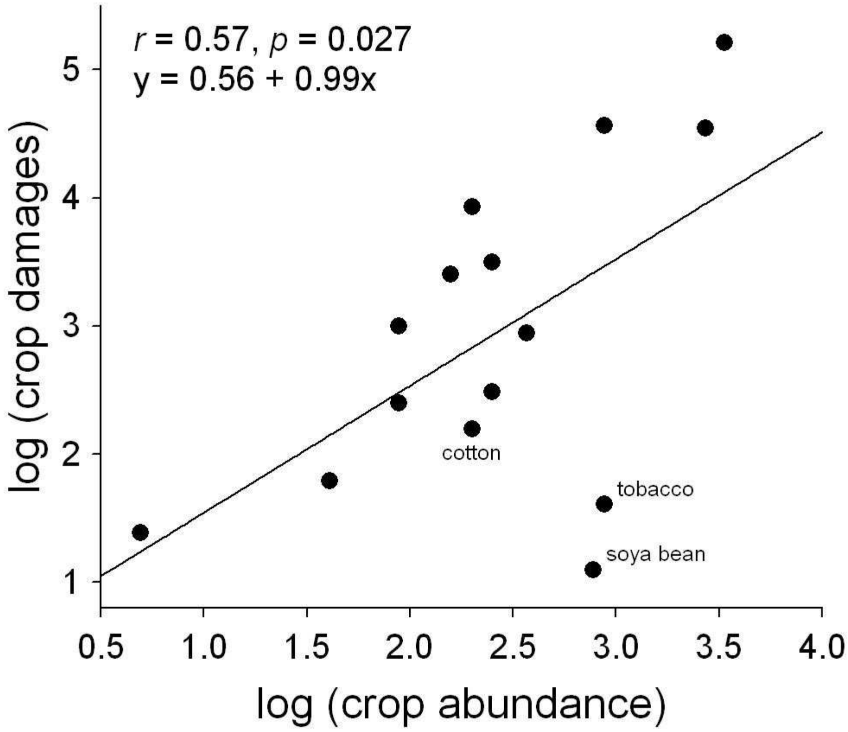

Fig. 3. Relationship between the number of damages recorded for various crops and their abundance (number of villages where the respective crop is frequently cultivated) described by a linear regression model. Cotton and tobacco (indicated in the graph) were only damaged accidentally by passing elephants but were not used as food. Furthermore, damages of soya bean fields (indicated in the graph) were remarkably rare.

Seasonality of crop availability and elephant incidents

Two distinct peaks of elephant incidents during the course of a year were recorded. The highest frequency of incidents occurs at the end of the wet season when crops like maize (and peanut) are fully ripe but not yet ready for harvesting which is done when the crop is dried on the field. Crop raiding events decrease with progressing dry season. Then, the number of recorded elephant incidents is increasing again at the transition period between dry and wet season (Fig. 4).

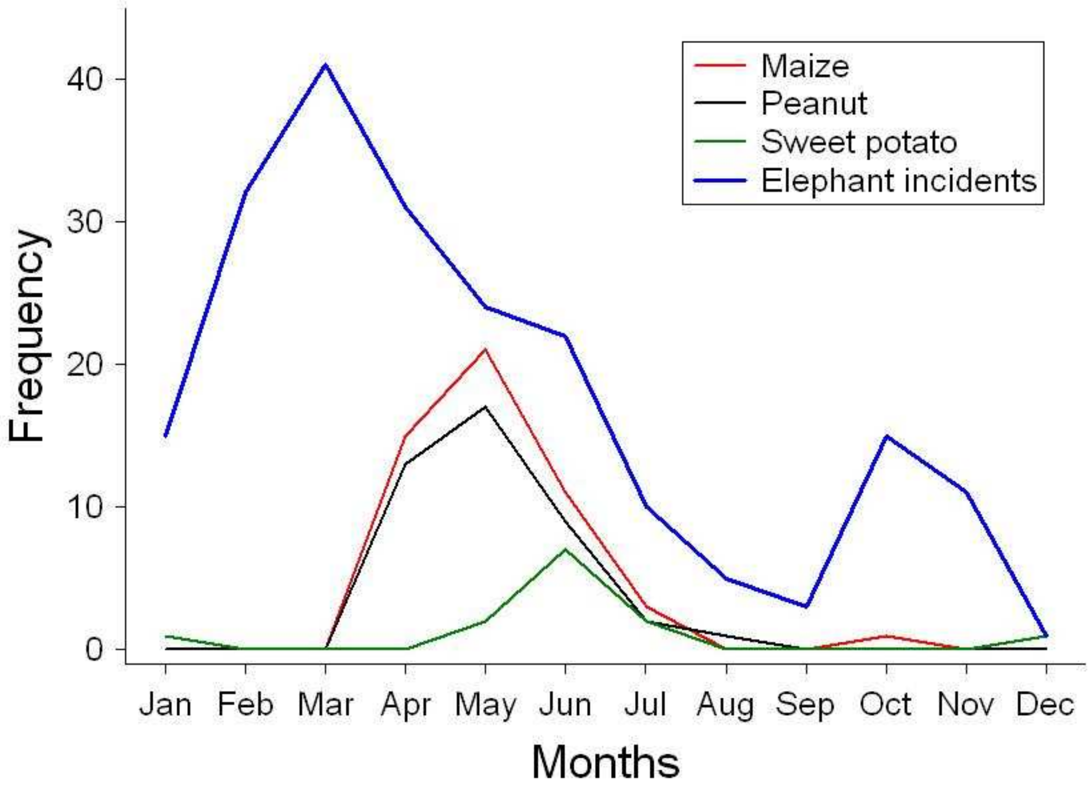

Fig. 4. Seasonality of elephant incidents (total number of records per months) and harvesting time of three frequently damaged by elephants. Harvesting time of crops was quantified as the total number of villages were the crop was harvested in the respective months.

Spearman rank correlations testing for relationships between the number of recorded damages and the frequency of harvesting of the three most abundant crops in individual months did not show any significant relationships (Tab. 2). Still no significant relationships were found when relating crop damage recorded for individual months to the frequency of availability of crops in a growth stage one month before harvesting. However, the number of recorded damages by elephants was positively correlated to the availability of the respective three crops maize, peanut and sweet potato two months before harvesting. These relationships even remained significant for maize and peanut after applying a Bonferroni correction (Tab. 2).

Table 2. Results of Spearman rank correlations between the number of crop damages and crop availability (number of villages where crops are harvested in the respective months) at harvesting time, and 1 and 2 months before harvesting time, separately analyzed for the three crops maize, peanut and sweet potato. * indicate results which remained significant after applying a Bonferroni correction.

Crop type	Crop availability	r_s	p
Maize	at harvesting time	0.01	0.986
	1 month before harvesting	0.54	0.073
	2 months before harvesting	0.70	0.011*
Peanut	at harvesting time	0.20	0.536
	1 month before harvesting	0.58	0.048
	2 months before harvesting	0.83	<0.001*
Sweet potato	at harvesting time	0.34	0.259
	1 month before harvesting	0.52	0.080
	2 months before harvesting	0.63	0.029

We further tested, if elephant incidents (crop raiding) occurred more frequently during the dry season (compared to wet season) in villages with irrigations than in villages without irrigation. While the number of elephant incidents was relatively similar between wet (10 incidents) and dry season (13 incidents) in villages with irrigation, twice as many incidents could be recorded for villages without irrigation during the wet season (121) compared to the dry season (66). This difference proved to be significant (Chi-square test: $\chi^2 = 3.94$, df = 1, $p = 0.047$). However, no significant differences of crop availability (crops two months before harvesting) between wet and dry season were found between villages with and without irrigation (Chi-square tests; for all three crop types: $p > 0.4$).

Spatial pattern of elephant occurrences

The risk of elephant incidents in the study villages declined significantly with increasing distance of villages from the reserve's boundary (Fig. 5). This pattern was even more pronounced when only considering elephant incidents recorded during the wet season (Fig. 6a), but did not achieve significance for the dry season, for which an even opposite trend is indicated by the logistic regression (Fig. 6b).

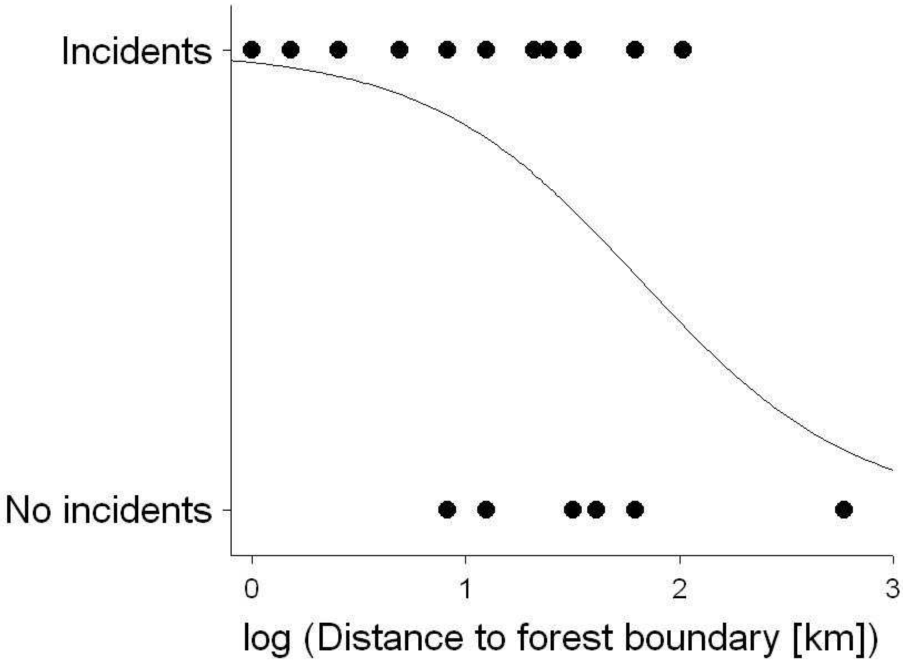

Fig. 5. The likelihood of elephant incidents is decreasing with increasing distance of villages from the margin of Thuma Forest Reserve (logistic regression; χ^2= 7.66, p = 0.006).

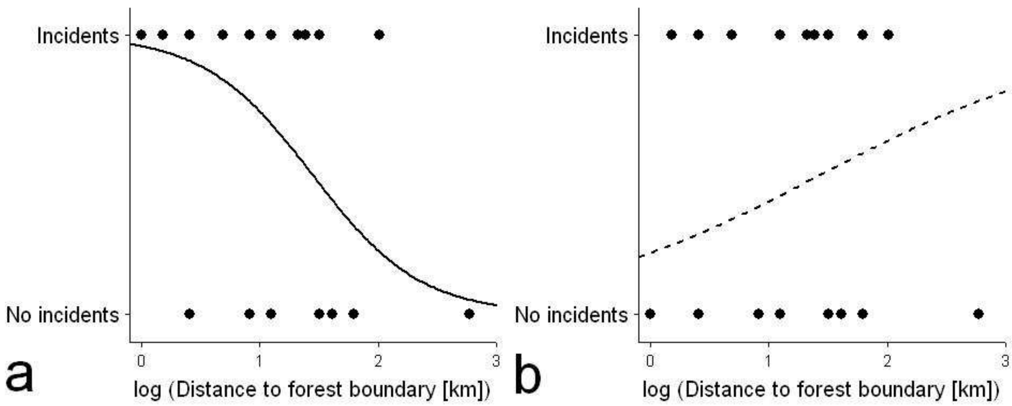

Fig. 6. The occurrence of elephant incidents in villages located in different distances to the margin of Thuma Forest Reserve separately analyzed for (a) wet season (logistic regression: χ^2= 10.48, p = 0.001) and (b) dry season (logistic regression: χ^2= 2.80, p = 0.094).

Univariate analyses (using Wald statistics) of predictors in a GLM testing for effects of season, distance of village to forest margin and their interaction on the occurrence of elephant incidents indicates that season and the interaction between season and distance of villages to the forest margin significantly predicted elephant incidents, while distance to the forest margin did not significantly affect the likelihood of elephant incidents (Tab. 3). That distance to the forest margin alone did not affect the likelihood of an occurrence of elephant incidents may be caused by the pronounced seasonal differences already described above (compare Fig. 6).

Table 3. Univariate analyses (Wald statistics, df = 1) of predictors in a GLM testing for effects of season, distance of village to the border of TFR and their interaction on the occurrence of elephant incidents.

Effect	**Wald statistic**	***p***
Constant	2.17	0.141
Season	11.74	<0.001
log (distance to TFR)	1.62	0.203
Season X log (distance to TFR)	8.88	0.002

Group size

A GLM testing for effects of daytime, month, distance to TFR and irrigation on elephant group size (multiple r = 0.37, multiple r^2 = 0.14, $F_{4,112}$ = 4.38, p = 0.002) indicated that only season significantly affected group size (Tab. 4). The mean size of elephant groups (± SD) was 10.87 (± 9.56) individuals. Lowest mean group size was recorded in January and increased continuously with progressing seasons until May. Then it appeared to remain similar until December (Fig. 7).

Table 4. Results of a GLM testing for effects of daytime, irrigation, months and distance to TFR on the size of elephant groups reported by farmers.

Effect	**df**	**MQ**	***F***	***p***
Constant	1	29.028	45.31	0.000
Diurnal or nocturnal activity	1	0.562	0.88	0.351
Irrigation	1	0.002	0.00	0.954
Months	1	7.612	11.88	0.001
Distance to TFR	1	0.208	0.32	0.569
Error	112	0.640		

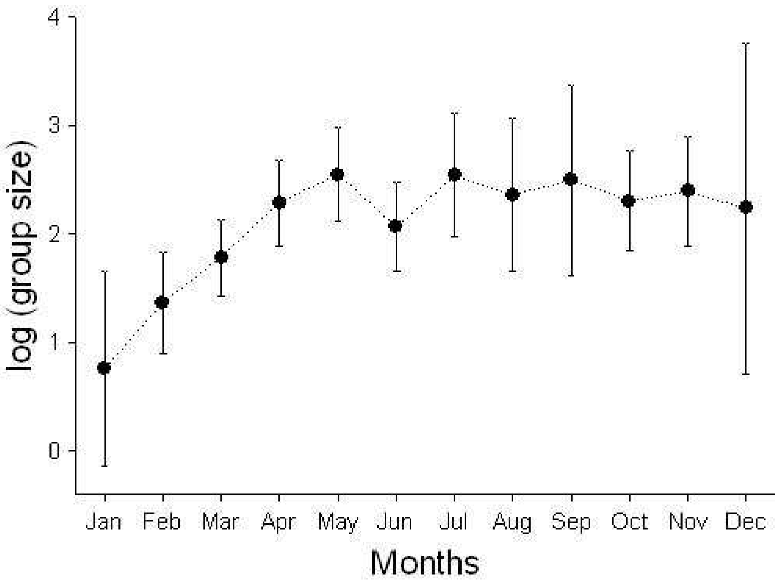

Fig. 7. Least means squares of elephant group sizes (± 95% confidence intervals) as recorded outside the forest reserve in different months.

Effects of the electric fence on elephant incidents

The electric fence significantly decreased the likelihood of elephant incidents in villages behind the fence compared to unprotected villages (Chi-square test: χ^2 = 9.38, p = 0.002). In villages without fence the number of incidents remained relatively constant between the wet season Dec. 2008-March 2009 (19 incidents) and Dec. 2009-March 2010 (17 incidents), while in villages behind the fence the number of incidents declined from 17 in Dec. 2008-March 2009 to only 1 in Dec. 2009-March 2010.

Discussion

Crop preferences and seasonality of human-elephant conflicts

Crop-raiding elephants were a common phenomenon in the agricultural land at the margin of TFR. However, the number of reported crop damages in our study area followed a seasonal pattern with a large peak in the wet season, and small peak at the end of the dry season. The highest frequency of crop raiding incidents did not occur during harvesting time of major crops but two months before (in March) indicating that elephants do prefer earlier growth stages of crops, while ripe crops are less attractive. Crops such as maize are harvested when the plant is dried on the field. At this stage the corn cob becomes difficult to chew which increases handling time. Additionally palatability may decrease compared to two months before harvesting when the liquid content of crops is still higher. Also for Zimbabwe with a similar seasonal climate a highest crop raiding activity was documented for March (Parker & Osborn 2001).

A second much smaller peak of crop-raiding activity is reached in October and may correspond to the maturing of maize in villages where irrigation is conducted. At least our results indicate that for the dry season – compared to the wet season – relatively more elephant incidents were reported from villages with irrigation than from villages without irrigation. However, our data on crop availability did not show that during the dry season major crops were more frequently cultivated in villages with than without irrigation. Perhaps quantitative data (instead of only qualitative data on harvesting times of crops) providing information on the amounts of harvested crop would have been necessary to reliably testing for effects of crop availability on the occurrence of elephant incidents.

Besides crop availability, another factor potentially affecting the occurrence of elephant incidents in villages with irrigation has to be considered. Especially villages along larger rivers are conducting irrigation. These rivers partly mark the border of TFR. When the water level of these rivers is rising during the rainy season, elephants may not be able to cross them anymore. Therefore, particularly during the peak of the wet season, these rivers may act as natural barrier protecting villages against crop-raiding elephants. Hence, villagers along Lilongwe river did not report any elephant incidents during time periods with heavy rainfall resulting in high water levels.

Preferences in food selection by elephants could not be detected in this study. The abundance of crop-raiding only appeared to reflect crop availability in our study area. For example, maize was most frequently affected by crop-raiding elephants and was most often mentioned by village heads as one of the major cultivated crops. Besides availability, the nutrient content of food plants appears to be an important criteria for food (crop) selection of elephants. A study on seasonal variation of feeding patterns and food selection by crop-raiding elephants in Zimbabwe reported an increasing crop-raiding activity when the quality of wild grasses as food source of elephants is declining below the quality of crops (Osborn, 2004). Other natural food sources of elephants such as bark or other parts of woody plants, which require extra handling time, may be even permanently less attractive than cultivated crops. Many crops provide a high energy intake rate, retain high nutrient values even as adult plants, and require shorter handling times during feeding due to less developed chemical and physical defense mechanisms against large herbivores (Osborne, 2004). Therefore, crops are a highly attractive alternative to food sources available to elephants in their natural habitats. The selection of food plants by elephants appears to be predominantly determined by their nutritional value at any given place or time (Osborne, 2004). This seems to explain why elephants preferentially use crops (especially in their phase of highest nutritious level) whenever they are available.

Spatial patterns of elephant incidents

Due to the relatively small size of TFR the distance between most locations within the reserve and the nearest cultivated areas with highly nutritious crops outside the protected forest is short. Probably because of this energy-economic option of getting access to highly attractive food sources crop raiding occurs very frequently in the surroundings of TFR. The significant use of non-conservation areas was recorded by many studies about ranging behavior of elephants (e.g. Fernando et al., 2008). The size of home ranges indicates resource requirement and habitat preferences. Home range size approximately varied from 30-230 km^2 in a study about Asian elephants in Sri Lanka and a high home range fidelity was observed (Fernando et al., 2008). The widest known variation of home range size, was found in a population of African elephants in northern Kenya and varied between 102 to 5527km^2 (Thouless, 1996). In the Rajaji Nationalpark (northwest India) it was found out that crop damage by elephants only occurred within their home ranges (Williams et al., 2001). TFR covers an area of about 197km^2. The home range size of the elephant population in TFR may therefore overlap with cultivated land. This implicates that resources outside conservation areas are important for the survival of elephant populations restricted to relatively small reserves (Fernando et al., 2008).

A study in Muzarabani district, Zimbabwe showed that the vast majority of elephant incidents occurred within distance of 5 km from the reserve’s boarder (Parker & Osborn, 2001). In our study elephant incidents were recorded up to a village which is located about 6,5km from the boundary of TFR.

Group size of crop raiding elephants

Elephants live in matriarchal societies. The basic social units are stable groups of several related females and their offspring. Females remain in their families while males become independent upon reaching sexual maturity (Kangwana, 1996). Unfortunately, the majority of interviewed farmers in this study could not provide any information on the sex of elephants involved in crop-raiding incidents. However, crop raiding was almost exclusively done by groups of elephants mostly with juveniles, which indicates a high ratio of adult females with subadult males and females among crop-raiding individuals at TFR. In other studies predominantly males were identified as crop raiders (Hoare, 1999; Sukumar, 1990). In Asian elephants this is explained by a high risk taking behavior (conflict with people): extra nutrition may enhance reproductive success (Sukumar, 1990).

The group size of crop raiding elephants varied seasonally. From January until March the group size increased continuously, similar to the increase of elephant incidents from January until March. The increasing group size at this time of the year may be related to the maturity of particular crops. The progressing maturity of crops, like maize, seems to attract more individuals in this time period. In Zimbabwe the start of crop raiding seems to begin at the transition to the late wet season which indicates a link to the quality of grass as elephant food at the end of the wet season. The nutrient content of grass becomes very low when it matures. Therefore crop raiding may be predicted from grass growth, which is closely related to rainfall patterns (Osborn, 2004). This means in times when the food quality inside the reserve is adequate for elephants and the crops not yet have reached their highest nutritional value, less individuals choose to leave the reserve and therefore the group sizes are smaller.

Implications for elephant management at Thuma forest reserve

The high frequency of crop raiding by elephants around TFR may be the result of the close proximity of agricultural land providing highly attractive food sources. In addition a probably increasing elephant population will intensify the problem due to increasing competition for resources inside their natural habitat. In consequence the needs for food sources cannot be satisfied by the protected forest area due to its relatively small size (although TFR is connected with the elongated Dedza-Salima Forest Reserve which covers an area of about 320 km^2). However, crop raiding is also determined by the attractiveness of crops probably irrespective of elephants´ home range needs. A combination of both factors, home range size and a high quality of crops as food source, is likely to cause crop raiding. The development of sustainable solutions for the human-elephant conflict therefore is extremely challenging.

In my study crop raiding in TFR could not be clearly traced back to a few problem elephants. Therefore, conflict-reducing strategies like the relocation of individual animals or even culling (which is ethically debatable) are no adequate options in case the population size does not exceed the caring capacity of TFR. In general farmers try to reduce crop-raiding events through the use of traditional methods for chasing elephants such as playing drums and lighting fires (own data, unpublished). Just recently an electric fence was build at the eastern border of TFR to further decrease crop-raiding. Our analyses indicated that electric fencing is a very promising measure (in case maintenance is done properly) and most likely fencing of the whole TFR would dramatically reduce crop-raiding events. For the villages at the margin of TFR, which are affected by crop-raiding, this would be a highly welcomed solution. But in terms of conservation generally this is a very insufficient option concerning migration behavior and genetically exchange. On the other hand an incomplete fencing of the forest reserve may not reduce the problem in a long term, but may shift the problem to other previously less affected villages. In case of sufficient financial resources the development and implementation of governmental compensation programs and insurance schemes as long term mitigation measures are imaginable. Currently, compensation for elephant damages is carried out by the Botswana Government, although compensation schemes are largely viewed as a failure due to its liability to corruption. However, local insurance schemes introduced in Namibia seem to be effective. Only registered members (all members pay into the system) receive payments to compensate losses caused by elephants. Therefore in this system there are less opportunities for corruption. (Parker et al., 2007). On a smaller scale (individual crop fields or villages) other measures can be implemented to reduce crop damage, such as using the sound of disturbed African bees, which acts as an acoustic elephant deterrent (King et al, 2007), or Chilli-based deterrents (Hedges & Gunaryadi, 2009). Another possibility is to promote non-agricultural income sources.

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References

Chiyo, P.I. & Cochrane, E.P. 2005. Population structure and behaviour of crop-raiding elephants in Kibale National Park, Uganda. African Journal of Ecology 43: 233–241.

Chiyo, P.I., Cochrane, E.P., Naughton, L. & Basuta, G.I. 2005. Temporal patterns of crop raiding by elephants: a response to changes in forage quality or crop availability? African Journal of Ecology 43: 48–55.

Fall, M.W. & Jackson, W.B. 2002. The tools and techniques of wildlife damage management—changing needs: an introduction. International Biodeterioration & Biodegradation 49: 87–91.

Fernando, P., Wikramanayake, E.D. & Janaka, H.K. 2008. Ranging behavior of the Asian elephant in Sri Lanka. Mammalian Biology 73: 2–13.

Hart, L.A. & O'Connell, C.E. 1998. Human conflict with African and Asian Elephants and associated conservation dilemmas. Proceedings from the Workshop on Cooperative Regional Wildlife Management in Southern Africa. http://www.agecon.ucdavis.edu/people/faculty/ facultydocs/Jarvis/elephant/hart-oconnell.pdf (last accessed: 23 August 2010)

Hedges, S. & Gunaryadi, D. 2009. Reducing human–elephant conflict: do chillies help deter elephants from entering crop fields? Oryx 44: 139–146.

Hoare, R.E. 1999. Determinants of human-elephant conflict in a land-use mosaic. Journal of Applied Ecology 36: 689–700.

Hoare, R.E. 1999. Data Collection and Analysis Protocol for Human-Elephant conflict Situations in Africa. African Elephant Specialist Group's Human-Elephant Conflict Working Group, Nairobi.

Hoare, R.E. 2003. Fencing and other barriers against problem elephants. AfESG Technical Brief Series. http://www.african-elephant.org/hec/pdfs/hecfencen.pdf (last accessed: 26 August 2010)

Jackson, T.P., Mosojane, S., Ferreira, S.M. & van Aarde, R.J. 2008. Solutions for elephant *Loxodonta africana* crop raiding in northern Botswana: moving away from symptomatic approaches. Oryx 42: 83–91.

Jury, M.R. & Mwafulirwa, N.D. 2002. Climate variability in Malawi, Part 1: Dry summers, statistical associations and predictability. International Journal of Climatology 22: 1289–1302.

Kangwana, K. (Editor). 1996. Studing Elephants. African Wildlife Foundation Technical Handbook Series 7. http://207.97.202.121/documents/AWF_7_studying_elephants_eng.pdf#page=10 (last accessed: 15 September 2010)

King, L.E., Douglas-Hamilton, I. & Vollrath, F. 2007 African elephants run from the sound of disturbed bees. Current Biology 17: 832–833.

Kioko, J., Muruthi, P., Omondi, P. & Chiyo, P.I. 2008. The performance of electric fences as elephant barriers in Amboseli, Kenya. South African Journal of Wildlife Research 38: 52–58.

Martin, J., Chamaille´-Jammes, S., Nichols, J.D., Fritz, H., Hines, J.E., Fonnesbeck, C.J., MacKenzie, D.I. & Bailey, L.L. 2010. Simultaneous modeling of habitat suitability, occupancy, and relative abundance: African elephants in Zimbabwe. Ecological Applications 20: 1173–1182.

Ministry of Natural Resources, Energy and Environment. 2006. Climate of Malawi. http://www.metmalawi.com/climate/climate.php. (last accessed: 30 August 2010)

Naughton, L., Rose, R. & Treves, A. 1999. The social dimensions of human-elephant conflict in Africa: A literature review and case studies from Uganda and Cameroon. Report to the African Elephant Specialist, Human-Elephant Task Conflict Task Force, of IUCN, Glands, Switzerland.

O'Connell-Rodwell, C.E., Rodwell, T., Rice, M. & Hart, L.A. 2000. Living with the modern conservation paradigm: can agricultural communities co-exist with elephants? A five-year case study in East Caprivi, Namibia. Biological Conservation 93: 381–391.

Osborn, F.V. 2004. Seasonal variation of feeding patterns and food selection by crop-raiding elephants in Zimbabwe. African Journal of Ecology 42: 322–327.

Osborn, F.V. & Parker, G.E. 2001. Dual season crop damage by elephants in the Eastern Zambezi Valley, Zimbabwe. Pachyderm 30: 49–56.

Osborn, F.V. & Parker, G.E. 2002. Community-based methods to reduce crop loss to elephants: experiments in the communal lands of Zimbabwe. Pachyderm 33: 32–38.

Parker, G.E., Osborn, F.V., Hoare, R.E. & Niskanen, L.S. 2007. Human-Elephant Conflict Mitigation. A Training Course for Community-Based Approaches in Africa. IUCN/SSC African Elephant Specialist Group. http://www.african-elephant.org/hec/pdfs/heccombappmen.pdf (last accessed: 26 August 2010).

Schenk, A.C. 2008. Thuma Forest Reserve Mammal Survey 2006. Wildlife Action Group. http://www.wildlife-malawi.com/ThumaFR_Mammal _Survey_2006.pdf (last accessed: 23 August 2010).

Sitati, N.W., Walpole, M.J. & Leader-Williams, N. 2005. Factors affecting susceptibility of farms to crop raiding by African elephants: using a predictive model to mitigate conflict. Journal of Applied Ecology 42: 1175–1182.

Sitati, N.W., Walpole, M.J., Smith R.J. and Leader-Williams, N. 2003 Predicting spatial aspects of human–elephant conflict. Journal of Applied Ecology 40: 667–677.

Smith, R.J. & Kasiki, S.M. 1999. A Spatial Analysis of Human-Elephant Conflict in the Tsavo Ecosystem. African Elephant Specialist Group report, IUCN/SSC.

Statsoft.Inc. 2005. STATISTICA (Data Analysis Software System), Version 7.1. www.statsoft.com.

Sukumar, R. 1994. Wildlife-Human Conflict in India: An Ecological and Social Perspective. In: Guha, R. (ed.) Social Ecology , Oxford University Press, New Delhi. Pp. 303-317.

Sukumar, R. & Gadgil, M. 1988. Male differences in foraging on crops by Asian elephants. Animal Behaviour 36: 1233–1235.

Sukumar, R. 1991. The management of large mammals in relation to male strategies and conflict with people. Biological Conservation 55: 93–102.

Tchamba, M.N. 1996. History and present status of the human/elephant conflict in the Waza-Logone Region, Cameroon, West Africa. Biological Conservation 75: 35–41.

Thouless, C.R. 1996. Home ranges and social organization of female elephants in northern Kenya. African Journal of Ecology 34:284–297.

Thouless, C.R. & Sakwa, J. 1995. Shocking Elephants: Fences and crop raiders in Laikipia District, Kenya. Biological Conservation 72: 99–107.

van Aarde, R.J., Jackson, T.P. & Ferreira, S.M. 2006. Conservation science and elephant management in southern Africa. South African Journal of Science 102: 385–388.

Vidya, T.N.C. & Thuppil, V. 2010. Immediate behavioural responses of humans and Asian elephants in the context of road traffic in southern India. Biological Conservation 143: 1891–1900.

Wildlife Action Group – Malawi. 2009. Thuma Forest Reserve. http://www.wag-malawi.org/ (last accessed: 23 August 2010).

Williams, A.C., Johnsingh, A.J.T. & Krausman, P.R. 2001. Elephant-human conflicts in Rajaji National Park, Northwestern India. Wildlife Society Bulletin 29: 1097–1104.

Zhang, L. & Wang, N. 2003. An initial study on habitat conservation of Asian elephant (*Elephas maximus*), with a focus on human elephant conflict in Simao, China. Biological Conservation 112: 435–459

Appendix A

Questionnaire for village chief

Name of village: ____

Name of village chief: ____

Number of village inhabitants: ______________

Irrigation: No Yes

Main crops (Ranking according to their area) and harvest time:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1. __________________________												
2. __________________________												
3. __________________________												
4. __________________________												

Occurrence of elephants during the last 6 months?

No Yes How often?_______

Occurrence of elephants before?

No Yes

"Victims" – Names of villagers

1.________________________________

2.________________________________

3.________________________________

4.________________________________

Appendix B

Elephant Incident Form

Village: ____

Interviewee Name: ______________________________________

Date: ____________________

Daytime: __________________

Group size, age and sex: ______________________________

Type of incident (observation only, crop damage, attack of humans, others …)

____

When crop damage:

Type of damage ☐ accidental damage e.g. by trespassing only

☐ crop raiding

Damaged crop ______________________________

Damaged parts of crop (roots, fruits, seeds etc.)

____

Other Damages (stored food, food storage, fences etc.):

____

Direct human-elephant conflict?

☐ Yes ☐ No

When yes:

☐ Human Injury

☐ Human Death

☐ Others: ______________________

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